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Pressure Visualization (PreViz) Package Version 1.0 User's Guide

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Preface

This document describes the Pressure Visualization (PreViz) Package release 1.0. It is intended to serve as a tutorial for new users and as a reference manual for experienced users. New users are directed to read the introductory section, then work through the sample session presented in appendix A. Sections 2-6 must be read in part or in whole before PreViz may be used successfully for a new application. All readers should be familiar with their host computer and its operating system.

This software was developed by Computer Sciences Corporation, Applied Technology Division, under contract to the National Aeronautics and Space Administration's Langley Research Center, during the Summer of 1988. CSC supports this package only at Langley Research Center.

Table of Contents

Introduction

The Pressure Visualization (PreViz) package is a collection of computer programs which transforms raw aerodynamic experimental data into a 3-D geometric wireframe model of the test aircraft with displacement vectors placed at the pressure port locations. A simple model produced by this package is shown in figure 1.

Currently being used by various research groups at the NASA Langley Research Center, the PreViz package provides the following benefits:

- It significantly reduces the time used to review the large volume of data collected from a single test and presents the results more clearly than is possible with a tabulated data listing. This may allow the researcher to perform more tests, or conduct a more thorough investigation, even when a limited amount of time is available at a tightly scheduled facility.

- It allows the researcher to quickly compare the results from two or more tests. Unlike tabulated data listings or even color contour plots, PreViz uses displacement vectors to indicate the <u>magnitude</u> of Cp, which is standardized for all tests. Thus the researchers may compare multiple tests' results directly since all displacement vectors' magnitudes indicate a consistent measure of pressure.

- It provides the information necessary to create a black and white graphic suitable for inclusion in a technical publication. This option is quickly becoming a requirement for publication as more and more journal editors and technical readers are now accustomed to seeing detailed test results presented in graphic form.

- Although PreViz is designed for displaying pressure data, it works equally well using any surface properties, such as structural loading, skin temperature, ablative measures, or mass flux.

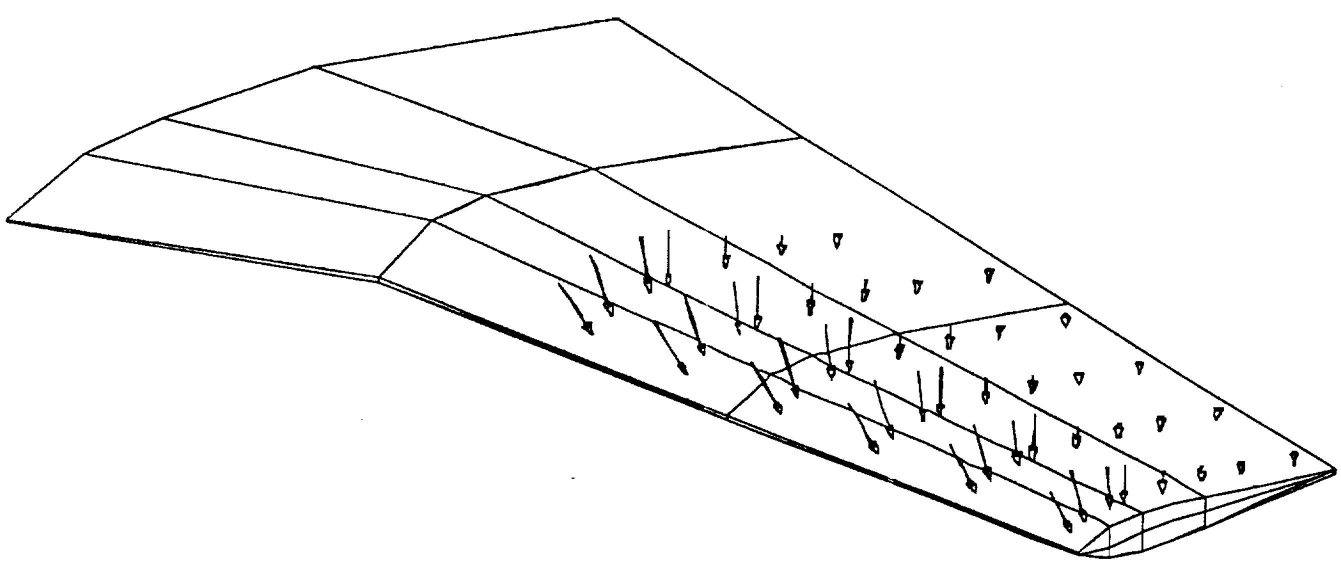

Figure 1. A Simple Displacement Vector Image

Overview of Use

There are three programs in the PreViz package. Each is used to perform a specific task:

G2TOAD transforms the pressure port geometry information into a PreViz format, to be used by program T2GEOM.

D2TOAD translates raw pressure data from its original wind tunnel format into a PreViz format, to be used by program T2GEOM.

T2GEOM uses the two files created by G2TOAD and D2TOAD to synthesize a 3-D wireframe model, including a series of displacement vectors, at the pressure port locations, normal to the aircraft's surface.

The entire process makes heavy use of the Langley Wireframe Geometry Standard (LaWGS) and the Transferable Output ASCII Data (TOAD) format, which are described in appendices B and C, respectively.

The general flow of information is presented in figure 2.

Normal Sequence of Events

Steps 1-5 are normally performed only once for any one test aircraft.

1. Digitize the test aircraft into a LaWGS file definition. This description is used only for display purposes. However, the amount of detail specified in the LaWGS file determines the degree of accuracy in the resulting images. Be aware that digitizing very large or very complex geometries may require extraordinary amounts of time and effort. Also be aware that processing very detailed LaWGS descriptions will require larger computer resources, and longer turnaround times.

2. Digitize the pressure port locations into a LaWGS file definition. The number and location of each pressure port is usually predetermined, and few (if any) variations are permitted. It is vital that all locations be on the surface of the aircraft.

3. Prepare a pressure port ID sequence. This is a "road map" which allows PreViz to assign the test aircraft's pressure port ID's to the pressure ports as defined in step 2.

4. Execute program G2TOAD. This prepares a master TOAD file containing the location of each pressure port, its global ID, and the direction cosines of the vector normal to the aircraft's surface at that location.

5. Modify program D2TOAD to extract the desired data from your wind tunnel raw data files. If more than one variable is desired, additional versions of D2TOAD must be prepared.

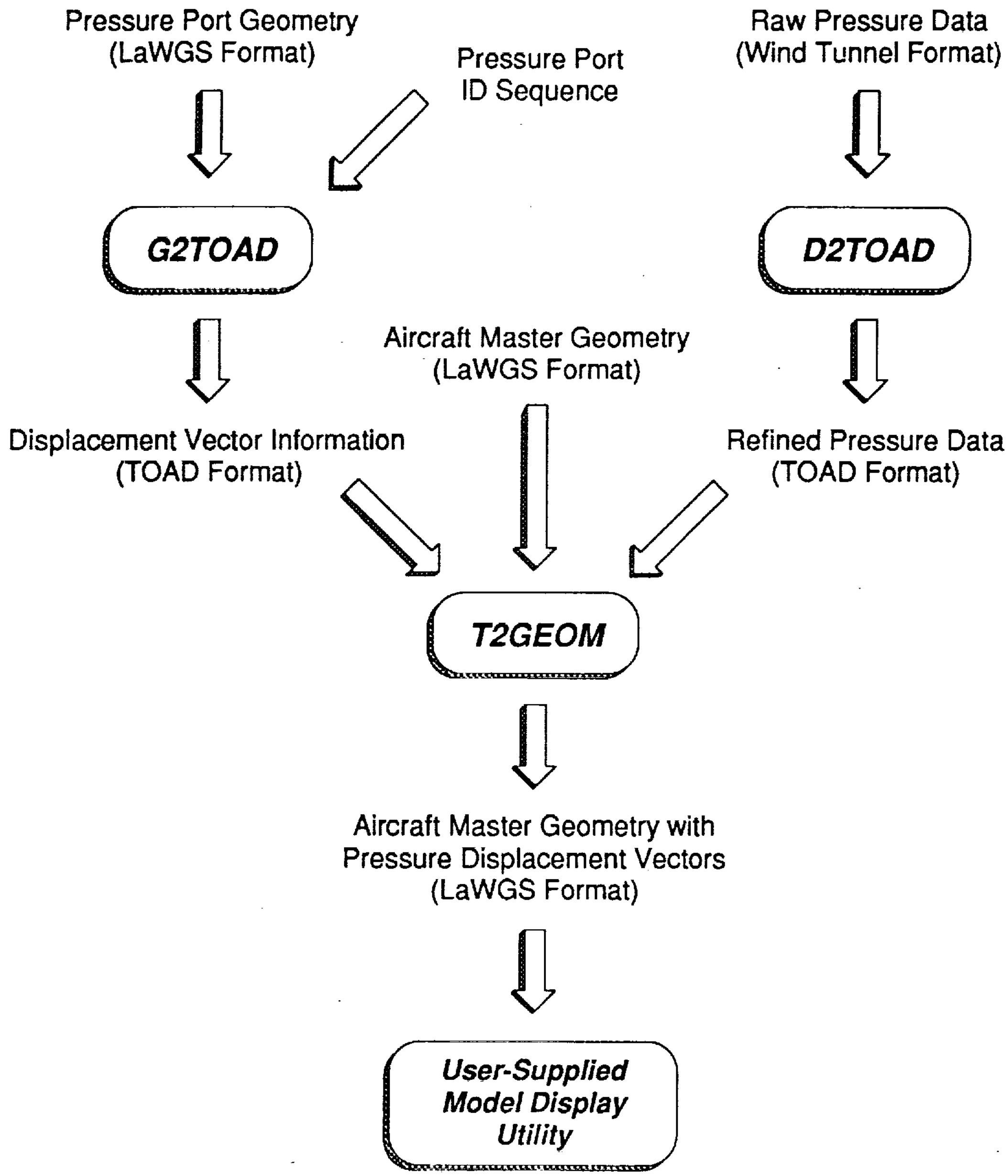

Figure 2. An Overview of the PreViz Package

Steps 6-8 are performed for every set of test results to be displayed.

6. Execute program D2TOAD. This prepares a TOAD file containing the test's raw data.

7. Execute program T2GEOM. This combines the aircraft geometry (step 1) with displacement vectors derived from the port TOAD file (step 4) and the raw data TOAD file (step 6) to create the final 3-D model as another LaWGS file.

8. With an appropriate graphics program, display this 3D model (the packages CODAC or PLOT3D are available to Langley users). It normally must be rotated into a series of different orientations in order to view all of the displacement vectors.

Note

Because many aspects of using the PreViz package are application-dependent, the general instructions presented in this section may be of limited use. We strongly recommend that you also review appendix A, a sample walk-through, for a detailed account of how the PreViz package was successfully used during an actual data visualization effort.

Preparing the Aircraft Geometry LaWGS File

The only purpose served by digitizing your aircraft geometry into a LaWGS file is to create a suitable object on which the pressure displacement vectors may be displayed. The amount of detail and/or completeness of the model is left to your discretion. We offer the following guidelines:

- Digitizing can be a lengthy and laborious task. Unless you already have the aircraft digitized in another format, we strongly recommend that you digitize as little of the aircraft as possible. If, for example, you are only interested in the wing's pressure readings, then we recommend that only the wing be digitized. This will significantly reduce your preparation time and provide a clearer medium for presenting the results.

- Even if the entire aircraft is to be digitized, remember that almost all configurations are symmetric across the XZ plane (i.e., the right and left sides are mirror images of each other). The LaWGS format accommodates such symmetry. We strongly recommend that you digitize only half of the aircraft, then set the appropriate indicator in the LaWGS file to create its mirror image.

- If your aircraft geometry is already digitized, consider writing a translator to convert it into LaWGS format. For more information concerning the LaWGS format, see appendix B. For a complete description, refer to NASA Technical Memorandum 85767.

Most aircraft can be broken up into many distinct components. For example, a commercial airliner contains a fuselage, a wing, a horizontal stabilizer, and a vertical tail. Prepare each component separately. This is particularly handy when a group is charged with creating the digital model -- each group member can work on an individual component. The resulting parallel effort will save significant amounts of calendar time.

Most components will have a "dominant" axis. For example, most aircraft fuselages are much longer than they are wide or tall. Thus, the body axis (X-axis) dominates. For an aircraft wing, the spanwise axis (Y-axis) usually dominates. For a vertical tail, the elevation axis (Z-axis) usually dominates. Using a fuselage as an example, imagine a knife "cutting" it into smaller sections along the dominant axis (in other words, since the X-axis dominates, the knife cuts parallel to the YZ plane). The result is a series of cross sections which, collectively, define the entire fuselage. Such cross sections are usually shown on the plans used by the manufacturer who built the aircraft. In LaWGS' vocabulary, each cross section's outer edge is called a "contour line." Each of these contour lines is defined as a series of "points." It is these points which we write into a LaWGS file. For example, the LaWGS file describing the forebody of a generic fighter aircraft looks like:

```
'FIGHTER #1'
'NETWORK 1'
 1 15 20 1 0. 0. 0. 0. 0. 0. 1. 1. 1. 0
    0.00000    0.00000    -.57300    0.00000    0.00000    -.57300
    0.00000    0.00000    -.57300    0.00000    0.00000    -.57300
    0.00000    0.00000    -.57300    0.00000    0.00000    -.57300
    0.00000    0.00000    -.57300    0.00000    0.00000    -.57300
    0.00000    0.00000    -.57300    0.00000    0.00000    -.57300
    0.00000    0.00000    -.57300    0.00000    0.00000    -.57300
    0.00000    0.00000    -.57300    0.00000    0.00000    -.57300
    0.00000    0.00000    -.57300    0.00000    0.00000    -.57300
    0.00000    0.00000    -.57300    0.00000    0.00000    -.57300
    0.00000    0.00000    -.57300    0.00000    0.00000    -.57300
    1.95676    0.00000   -1.00035    1.95646    -.06911    -.99904
    1.95463    -.16069    -.98480    1.95140    -.24971    -.95950
    1.94850    -.33150    -.91646    1.94404    -.40771    -.86687
```

1.93866	-.47456	-.80424	1.93145	-.53646	-.74044
1.92572	-.57746	-.65857	1.92026	-.60638	-.57360
1.91695	-.61800	-.48336	1.91976	-.59460	-.39505
1.92304	-.55566	-.31360	1.92926	-.49604	-.24464
1.93684	-.42396	-.18810	1.94439	-.34598	-.13940
1.95102	-.26345	-.09758	1.96007	-.17341	-.08083
1.96576	-.08123	-.06855	1.96334	0.00000	-.04997
3.94942	0.00000	-1.21171	3.94748	-.17549	-1.20568
3.94289	-.33567	-1.17544	3.93594	-.49152	-1.12913
3.92740	-.63797	-1.06042	3.91757	-.77393	-.97338
3.90660	-.89038	-.86534	3.89590	-.97985	-.73155
3.88245	-1.05121	-.58876	3.87124	-1.09294	-.43621
3.86559	-1.09621	-.27614	3.86337	-1.06245	-.11917
3.86992	-.97513	.01576	3.87644	-.86881	.13625
3.88682	-.73984	.23186	3.89895	-.59923	.31163
3.91368	-.44767	.36678	3.92297	-.29268	.41576
3.93272	-.13134	.43442	3.93470	0.00000	.44216
5.94786	0.00000	-1.36235	5.94647	-.21606	-1.35267
5.94094	-.43300	-1.31790	5.93254	-.64342	-1.25889
5.92220	-.84253	-1.16881	5.91060	-1.02418	-1.04936
5.89645	-1.18778	-.90526	5.88245	-1.30972	-.72626
5.86600	-1.40068	-.53158	5.85297	-1.44432	-.31893
5.84482	-1.44587	-.10222	5.83670	-1.41875	.11204
5.83529	-1.33391	.30950	5.83832	-1.20090	.47954
5.84836	-1.03176	.61549	5.86365	-.84324	.72298
5.88080	-.64333	.80848	5.89668	-.43191	.86199
5.90756	-.21692	.90041	5.91027	0.00000	.91710
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7.89551	-1.41509	-.93360	7.87986	-1.56475	-.72051
7.86395	-1.65140	-.47528	7.85364	-1.66402	-.21522
7.84426	-1.66356	.04556	7.83210	-1.64906	.30501
7.82627	-1.56434	.54973	7.82557	-1.41722	.76369
7.83108	-1.23046	.94452	7.84516	-1.01236	1.08655
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7.89314	-.26823	1.32030	7.89664	0.00000	1.34486
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9.92576	-1.13603	-1.27596	9.91321	-1.38716	-1.11621
9.90005	-1.58929	-.90109	9.88478	-1.73987	-.64669
9.86991	-1.79857	-.35917	9.85904	-1.80640	-.06314
9.84867	-1.79807	.23291	9.83688	-1.73892	.51946
9.82825	-1.64081	.79895	9.82434	-1.47851	1.03977
9.82718	-1.26174	1.24219	9.83988	-1.01281	1.40583
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11.92460	-1.30567	-1.26828	11.91168	-1.56926	-1.05230
11.89737	-1.78333	-.78818	11.88284	-1.89685	-.47362
11.86554	-1.91100	-.13316	11.85113	-1.90793	.20668
11.83755	-1.87309	.54405	11.82329	-1.75987	.86193
11.81531	-1.56187	1.13192	11.80763	-1.31878	1.36875
11.80241	-1.07889	1.60647	11.78656	-.97330	1.92187
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11.71564	-.30982	2.63064	11.70699	0.00000	2.69410
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15.89329	-1.99493	-.09327	15.88068	-1.99043	.27206
15.86940	-1.94306	.63355	15.85700	-1.80263	.96699
15.84870	-1.58545	1.25881	15.84126	-1.30568	1.49118
15.83069	-1.05191	1.74907	15.81291	-.96631	2.10474
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15.74666	-.35423	2.97268	15.73832	0.00000	3.06775
17.96434	0.00000	-1.75632	17.96401	-.36836	-1.72188
17.95971	-.71585	-1.64464	17.95434	-1.04651	-1.51410
17.94763	-1.34934	-1.32841	17.94042	-1.62110	-1.09795
17.93176	-1.79935	-.78841	17.92014	-1.89784	-.44784
17.90720	-1.93643	-.09432	17.89560	-1.93229	.26301
17.88423	-1.87137	.61349	17.87338	-1.73567	.94304
17.86423	-1.51419	1.22070	17.85773	-1.25144	1.46129
17.84883	-.99140	1.69915	17.83256	-.90344	2.04712
17.81480	-.79340	2.38660	17.79778	-.59982	2.68582
17.77460	-.32109	2.90693	17.76872	0.00000	2.99864
19.96823	0.00000	-1.72715	19.96711	-.31052	-1.68726
19.96243	-.63168	-1.60102	19.95625	-.93211	-1.46138
19.94878	-1.20395	-1.26938	19.93990	-1.43141	-1.02648
19.93309	-1.61018	-.74612	19.92454	-1.73049	-.43738
19.91668	-1.78943	-.11026	19.90582	-1.78440	.22320
19.89466	-1.72907	.55113	19.88508	-1.59698	.85689
19.87894	-1.41656	1.13549	19.87440	-1.19171	1.38159
19.86681	-.95909	1.61976	19.85160	-.88109	1.94575
19.83598	-.77443	2.26229	19.82076	-.60194	2.54417
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21.94001	-1.46522	-.74195	21.93187	-1.57088	-.45260
21.92375	-1.61632	-.14578	21.91349	-1.61195	.16346
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21.89158	-1.29655	1.02338	21.88930	-1.11026	1.27068
21.88270	-.90298	1.50091	21.86683	-.81271	1.79222
21.85236	-.71338	2.08333	21.83717	-.53485	2.33729
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23.94973	-1.43273	-.82841	23.94302	-1.53401	-.55203
23.93452	-1.58127	-.26314	23.92443	-1.57165	.03147
23.91538	-1.53148	.32323	23.90965	-1.46760	.61049
23.90506	-1.35893	.88456	23.90178	-1.19347	1.12735
23.89483	-1.00358	1.35240	23.87758	-.81172	1.57619
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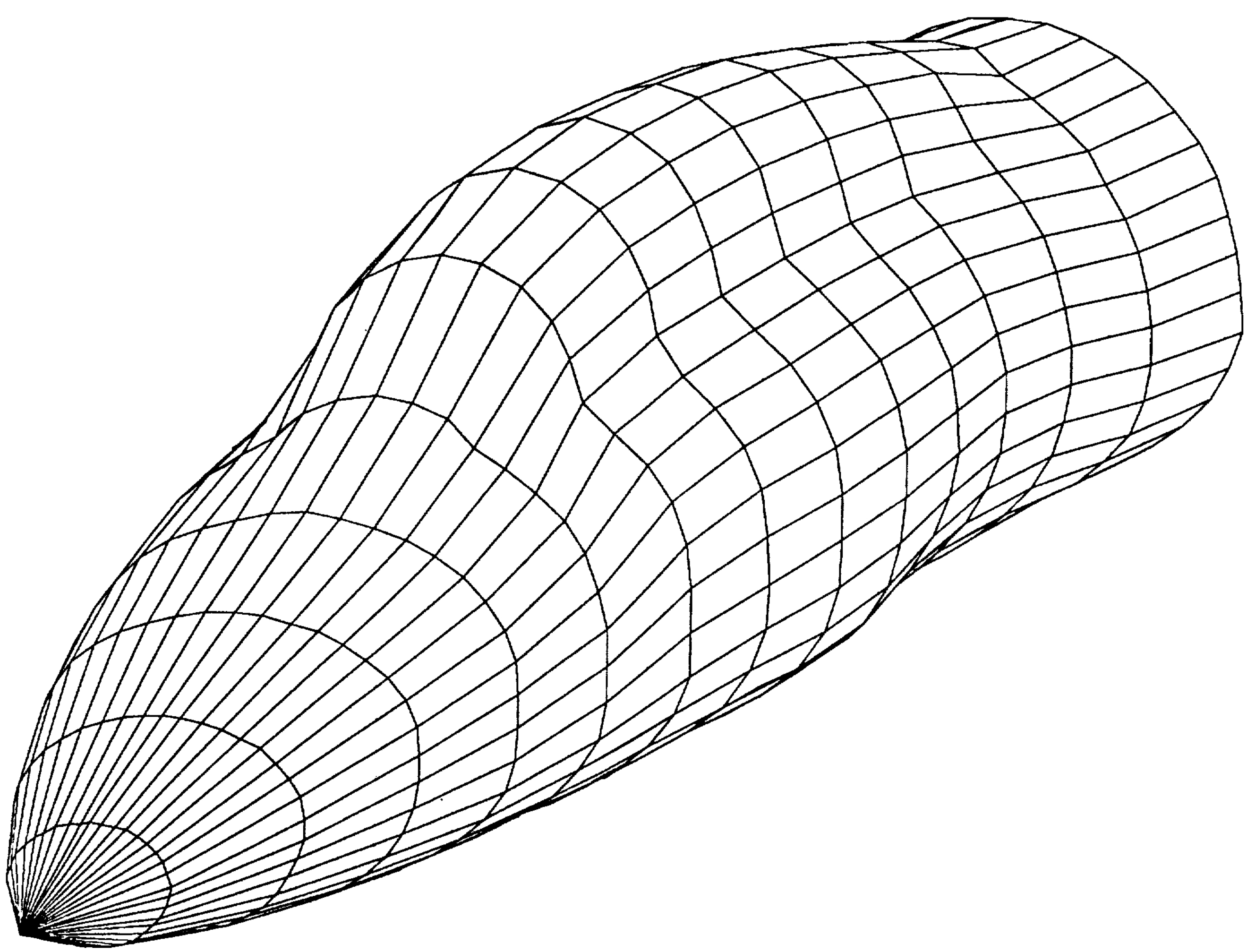
23.82691	-.27335	2.24489	23.82110	0.00000	2.30008
25.98033	0.00000	-1.70300	25.97934	-.28538	-1.67332
25.97660	-.56572	-1.61371	25.97231	-.83637	-1.52137
25.96577	-1.08912	-1.38585	25.95957	-1.31181	-1.20443
25.95489	-1.49262	-.98093	25.94851	-1.60798	-.71843
25.94042	-1.65705	-.43547	25.93074	-1.65288	-.14769
25.92187	-1.62168	.13818	25.91601	-1.55701	.41734
25.91191	-1.45038	.68461	25.90886	-1.30686	.93373
25.90143	-1.15659	1.17914	25.88478	-.96087	1.39237
25.86456	-.73493	1.57006	25.84670	-.50230	1.73479
25.83381	-.29890	1.93444	25.82772	0.00000	1.98088
27.98441	0.00000	-1.71269	27.98361	-.26624	-1.69488
27.98140	-.55879	-1.63485	27.97768	-.84419	-1.54831
27.97281	-1.12018	-1.43646	27.96770	-1.36206	-1.26052
27.96370	-1.56219	-1.04208	27.95648	-1.71617	-.78863
27.94549	-1.80705	-.50388	27.93850	-1.80293	-.20581
27.93173	-1.76383	.08975	27.92651	-1.70223	.38153
27.92201	-1.60978	.66399	27.91855	-1.46980	.92663
27.91370	-1.29303	1.16628	27.89944	-1.08742	1.38169
27.88297	-.84588	1.55520	27.86693	-.58390	1.69641
27.85374	-.30223	1.79105	27.84615	0.00000	1.81149

Using an appropriate display package, this LaWGS file produces the image:



which shows the fighter's cockpit section, as viewed from the pilot's forward, upper, left octant.

We strongly recommend that all cross sections used come from the manufacturer's plans. In addition, there is no need to digitize every cross section shown in the plans. Most configurations are clear using 5-10 cross sections, and even the most complex become clear with less than 20.

The cross sections do not need to be at equal intervals along the dominant axis. Deciding *which* cross sections to use and how they should be defined depends on the aircraft being modeled. You may find the following guidelines helpful:

- At first, space out the cross sections as evenly as the plans permit. We suggest using no more than 10 for the initial description.

- Look for transition areas, such as where the canopy begins and ends, engine inlets, or exhaust nozzles. Also, look for smooth areas which do not change along the dominant axis. The cross sections should be clustered around the transition areas, and sparse along the smooth areas. You may need to add more cross sections for complex configurations. This will probably be achieved through trial and error.

- Remember that LaWGS requires that all cross sections be defined using the same number of points. It does not, however, require that all points within a single contour line be unique. A common technique is to "double up" points at the smaller or simpler cross sections (such as the nose of the fuselage) and then "expand" them out as the cross sections become larger or more complex (such as the canopy or engine inlet area).

Preparing the Pressure Port LaWGS File

The pressure port LaWGS file, unlike the aircraft geometry LaWGS file, is not displayed directly. Rather, it controls the location and direction of the displacement vectors produced. It is therefore imperative that the pressure port LaWGS file be prepared with the utmost care and attention to detail.

Every pressure port collecting data to be displayed must be described -- data associated with omitted pressure ports cannot be displayed. Further, the (x,y,z) location provided should be very close to the aircraft's outer surface -- locations deep inside or far outside the configuration skin may create misleading graphical displays.

You may use any number and any combination of components, contour lines, and points to describe the pressure port locations. For example, if your wing has a 10 x 15 grid mesh of pressure ports, consider using a single component with 10 contour lines and 15 points per line. On the other hand, if the wing has two grid meshes, 5 x 12 and 7 x 12, consider using two components, one for each grid mesh. An example of a pressure port LaWGS file is presented in appendix A.

In aerodynamic research it is not unusual to see wind tunnel aircraft models with missing pressure ports within an otherwise regular grid mesh. Often this occurs when the pressure port is too close to an internal support structure, and cannot be properly milled or instrumented. Such an "irregular" mesh is difficult to describe using the LaWGS format.

Remember that the purpose of the pressure port LaWGS file is to provide an (x,y,z) location for each pressure reading, and not to provide a pressure reading for each port. We suggest that you create a "phantom" port for this void, creating a regular grid mesh, and allow the PreViz package to view it merely as a pressure port with missing data.

This technique can be extended for irregular meshes. For example, suppose a wing has three rows of pressure ports, with five, six, and three ports per row. By creating an imaginary 3 x 6 mesh, and creating phantom ports within those rows with less than six ports, the mesh becomes regular. And again, because the PreViz package ignores those ports with missing data, these phantom ports will not affect the resulting images.

Creating the Pressure Port TOAD File

The pressure port TOAD file provides three vital pieces of information for each pressure port: its (x,y,z) location, the direction vector of its surface normal (used to construct the displacement vector), and a unique identification index. There should only be one pressure port TOAD file for any test configuration.

Assuming you have already created the port LaWGS file, described in the preceding section, the next step is to create the port ID sequence file. It is a sequential, formatted, list-directed file, with the following contents:

> *number of ports described (integer)*
> *ID for the first pressure port (integer)*
> *ID for the second pressure port (integer)*
> .
> .
> *ID for the last pressure port (integer)*

(For readability, we recommend using only one value per record.)

The order of the pressure port ID's coincides with the order of (x,y,z) coordinates available from the pressure port LaWGS file. That is, the first ID is associated with the first (x,y,z) location, the second ID with the second location, and so on. There should be neither excess ID's nor excess (x,y,z) locations. The port ID's need not be sequential nor monotonic. Each ID should, however, be unique from all others.

Module G2TOAD uses the pressure port LaWGS file and its associated ID sequence file to create the pressure port TOAD file. How it is executed depends entirely upon the host operating system. However, most installations require only that you enter

g2toad

to start execution. Whatever the host operating system, the following welcome banner then appears:

```
-------------------------------------------

  Pressure Visualization Package (PreViz)

      Module G2TOAD      Release 1.0

-------------------------------------------
```

The first question asked is:

```
What is the name of the LaWGS file containing
the pressure port locations ?
```

Enter the name of your pressure port LaWGS file. If you want to stop G2TOAD, enter **quit**.

The second question is:

```
What is the name of the file containing the pressure port ID sequence ?
```

Enter the name of the ID sequence file. If you want to stop G2TOAD, enter **quit**.

The last question is:

```
What is the name of the new TOAD file being created ?
```

Enter what you want to call the new pressure port TOAD file. Retain this file for later use with the PreViz module T2GEOM.

This new TOAD file contains the following information for each pressure port: its ID number, its (x,y,z) location, and the (i,j,k) direction cosines of the surface normal at that location. The ID and (x,y,z) location come from the sequence file and port LaWGS file, respectively. However, the direction cosines are calculated by module G2TOAD. Looking at your pressure port grid mesh, it must decide which is the "outside" of the surface before it can construct surface normals. (Surface normals which point outward are desired - normals which point inward may create very strange images). G2TOAD assumes the more convex side should be outside and that the more concave side should be inside. Once established, all normals use the same convention and point off to the same side. If G2TOAD improperly selects the outside surface, the (i,j,k) direction cosines will all have the wrong sign. You can correct this by either editing the resulting TOAD file or modifying G2TOAD (subroutine NORMS).

Creating the Raw Pressure Data TOAD Files

Unless you are already using the TOAD format for data files, you will need to convert all raw data files into TOAD files. Module D2TOAD is a very simple program designed solely for this purpose.

D2TOAD makes only one assumption: that each pressure port's ID and raw data occur somewhere within the same record. You will probably need to change format 1100 (line 68) to match your data file(s). An example of how this format can be changed to match a data file is presented in appendix A.

Because you've changed source code, you will have to compile and load D2TOAD. If you have more than one type of raw data file to be converted, you may need many different versions of D2TOAD.

When executed, the following welcome banner then appears:

```
-------------------------------------------

  Pressure Visualization Package (PreViz)

      Module D2TOAD       Release 1.0

-------------------------------------------
```

The first question asked is:

```
What is the name of the raw data file to be read ?
```

Enter the name of your raw data file. If you want to stop D2TOAD, enter **quit**.

The second question is:

```
What is the name of the new TOAD file being created ?
```

Enter what you want to call the raw data TOAD file.

Module D2TOAD converts one file at a time. If you have several raw pressure data files, you should execute D2TOAD for each. When finished, you should have a new TOAD file for each of your original raw data files. Retain these TOAD files for later use with the PreViz module T2GEOM.

Creating the Pressure Visualization LaWGS Files

Module T2GEOM merges the aircraft geometry, pressure port information, and the raw data to create a LaWGS file containing the test configuration with displacement vectors indicating the reading at each pressure port. How it is executed depends entirely upon the host operating system. However, most installations require only that you enter

t2geom

to start execution. Whatever the host operating system, the following welcome banner then appears:

```
-------------------------------------------

  Pressure Visualization Package (PreViz)

      Module T2GEOM      Release 1.0

-------------------------------------------
```

The first question asked is:

```
What is the name of the TOAD file containing the pressure
displacement vector's direction cosines ?
```

Enter the name of the file you created with module G2TOAD. If you want to stop T2GEOM, enter **quit**.

The second question is:

```
What is the name of the file containing the refined pressure data ?
```

Enter the name of the file you created with D2TOAD. If there is more than one set of raw data, you will need to execute T2GEOM for each. If you want to stop T2GEOM, enter **quit**.

The third question is:

```
What is the name of the LaWGS file containing
the master aircraft geometry ?
```

Enter the name of the configuration geometry file. If you want to stop T2GEOM, enter **quit**.

The last question is:

```
What is the name of the new LaWGS file being created ?
```

Enter what you want to call the final LaWGS file.

You will probably want to change how T2GEOM determines the length of the displacement vectors. Within block data PRESET there are two symbolic constants: RMXDIS and RMXMAG. Parameter RMXDIS sets the maximum distance expected for the displacement vectors, measured in the same units as the configuration geometry description. Parameter RMXMAG sets the maximum magnitude of the pressure data to be displayed, expressed in the same units as the raw data. The two are then combined to create the vector transformation scheme. For example, if RMXDIS is 1000mm and RMXMAG is 5 atmospheres, the following table would result:

Raw Data (atmospheres)	***Displacement (mm)***
0.1	20
0.25	50
0.5	100
1.	200
2.	400
3.5	700
5.	1000
7.5	1500

Appendix A

Sample Walk-Through

The following walk-through documents actual events which occurred at Computer Sciences Corporation (CSC) during testing and acceptance of the PreViz package:

Research engineers working at one of NASA Langley's wind tunnels requested graphic displays showing each test's pressure data as a series of displacement vectors superimposed on a computer model of the aircraft being investigated. Both the aircraft and the pressure port locations had to be digitized. CSC requested:

- all geometry information regarding the test aircraft (for the aircraft geometry LaWGS file).
- all information concerning the pressure ports, to the extent that a list showing the port's id and its (x,y,z) location could be developed (for the pressure port LaWGS file).

CSC started with the aircraft plans. For clarity, four components were created: fuselage, wing, horizontal stabilizer, and vertical tail. CSC noted that all were symmetric side-to-side (XZ plane), and that the horizontal stabilizer was symmetric top-to-bottom (XY plane). Therefore, only the following regions were digitized:

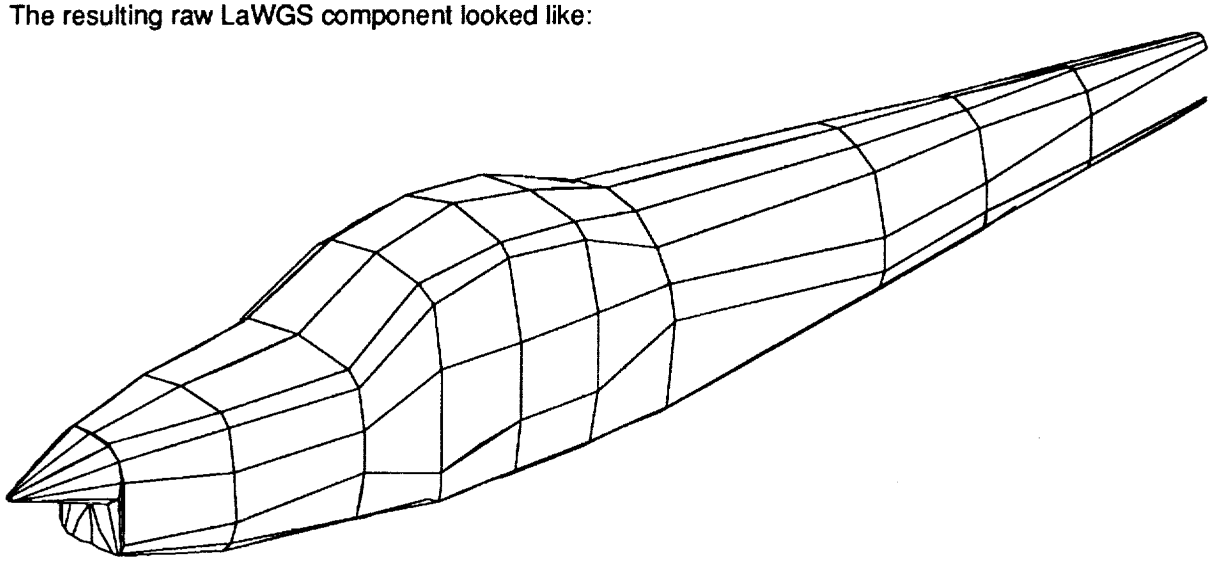
- the left half of the fuselage
- the entire left wing
- the top of the left horizontal stabilizer
- the left half of the vertical tail

The manufacturer's plans showed 32 cross sections for the fuselage. Fifteen cross sections were selected, at approximately even intervals. Nine points per cross section were used (the canopy area used ten), at about 30 degree increments. One additional cross section was used to refine the description near the engine inlet. Each cross section's contour line was digitized by hand from the drawings. Because the X-axis was dominant, only the (y,z) coordinates were recorded. A constant X value for each cross section was later added. The resulting raw LaWGS file contained:

```
'GENERIC TRAINER AIRCRAFT - CSC/NASA/LARC, 5/88'
'FOREBODY FUSELAGE, PORT SIDE'
1 6 9 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 1
0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
2. 0. -3. 2. 0. -3. 2. 2. -2.5 2. 3.5 -1. 2. 4. 1.
2. 4. 1. 2. 3.5 1. 2. 2. 4.5 2. 0. 5.
200. 0. -36. 200. 0. -36. 200. 22. -30. 200. 38. -16. 200. 42. 4.
200. 42. 4. 200. 37. 27. 200. 24. 40. 200. 0. 45.
201. 0. -86. 201. 26. -86. 201. 34. -83. 201. 40. -77. 201. 42. -70.
201. 42. 4. 201. 37. 27. 201. 24. 40. 201. 0. 45.
300. 0. -111. 300. 28. -110. 300. 55. -105. 300. 67. -93. 300. 72. -64.
300. 70. -9. 300. 62. 40. 300. 50. 52. 300. 0. 61.
429. 0. -122. 429. 28. -122. 429. 68. -113. 429. 77. -104. 429. 88. -47.
429. 88. 0. 429. 81. 46. 429. 66. 61. 429. 0. 70.
'MIDBODY FUSELAGE, PORT SIDE'
1 5 6 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 1
429. 0. -122. 429. 28. -122. 429. 68. -113. 429. 77. -104. 429. 88. -47.
429. 88. 0.
```

```
514. 0. -126. 514. 46. -124. 514. 71. -118. 514. 84. -116. 514. 90. -77.
514. 90. 40.
600. 0. -128. 600. 41. -127. 600. 75. -119. 600. 85. -109. 600. 93. -47.
600. 93. 40.
685. 0. -127. 685. 43. -126. 685. 73. -118. 685. 83. -109. 685. 93. -47.
685. 92. 40.
771. 0. -122. 771. 17. -122. 771. 71. -113. 771. 83. -101. 771. 93. 0.
771. 85. 40.
'AFTBODY FUSELAGE, PORT SIDE'
1 5 9 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 1
771. 0. -122. 771. 17. -122. 771. 71. -113. 771. 83. -101. 771. 93. 0.
771. 85. 40. 771. 68. 76. 771. 40. 105. 771. 0. 116.
1029. 0. -87. 1029. 10. -87. 1029. 50. -79. 1029. 60. -69. 1029. 66. -50.
1029. 66. -9. 1029. 49. 58. 1029. 28. 83. 1029. 0. 90.
1157. 0. -67. 1157. 15. -67. 1157. 36. -62. 1157. 44. -54. 1157. 49. -32.
1157. 49. 0. 1157. 34. 58. 1157. 20. 72. 1157. 0. 78.
1286. 0. -48. 1286. 8. -47.5 1286. 20. -46. 1286. 29. -38. 1286. 32. -27.
1286. 32. 24. 1286. 24. 49. 1286. 9. 64. 1286. 0. 65.
1430. 0. -26. 1430. 6. -25. 1430. 9. -24. 1430. 11.5 -21.5 1430. 12. -17.
1430. 12. 40. 1430. 10. 46. 1430. 4. 50. 1430. 0. 51.
'CANOPY - PORT SIDE'
1 5 4 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 1
429. 0. 70. 429. 66. 61. 429. 81. 46. 429. 88. 0.
514. 0. 133. 514. 59. 124. 514. 77. 108. 514. 90. 40.
600. 0. 159. 600. 63. 142. 600. 76. 129. 600. 93. 40.
685. 0. 144. 685. 62. 134. 685. 77. 119. 685. 92. 40.
771. 0. 116. 771. 40. 105. 771. 68. 76. 771. 85. 40.
```

The resulting raw LaWGS component looked like:



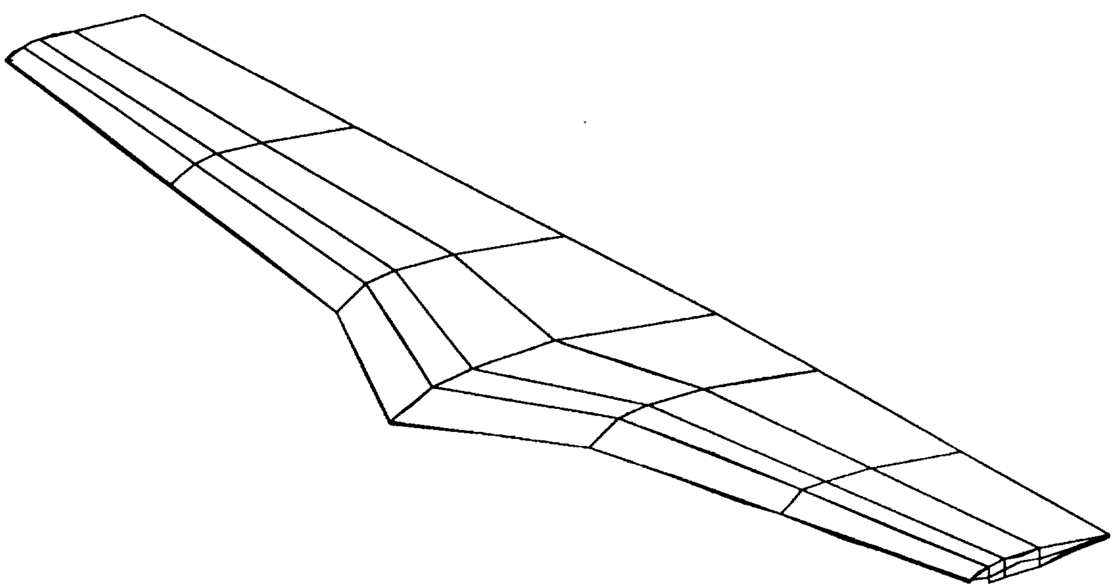
Fifteen cross sections were available for the wing, of which CSC selected three. Nine points per cross section were used, at 0% (leading edge), 25%, 50%, 75%, and 100% (trailing edge) chord locations, upper and lower faces. Because the upper and lower surfaces were not symmetric, both were digitized. Each cross section was recorded to begin at the trailing edge, trace along the lower surface, up around the leading edge, and then follow the upper surface back to the trailing edge, creating a "closed" contour. The trailing edge point appears twice for each cross section: as the very first point and as the very last point. An additional cross section was selected where the leading edge sweep angle changed abruptly.

Also, because the resulting leading edge was too sharp for accurate displays, an additional point was added to each cross section, in effect "blunting" the leading edge. Because the Y-axis was dominant, only the (x,z) coordinates were recorded. A constant Y value for each cross section was later added.

The wing's inboard cross section is at Y=0, the centerline, well inside the fuselage. An intersection between the wing and fuselage was not determined because the hidden-line display package used (CODAC) would automatically cut and remove from view the hidden surfaces. Finally, a fifth cross section was created at the wing's outboard tip, approximating the mean camber line. This served to "close off" the wing tip, preventing a side view from displaying the inside of the wing. The resulting raw LaWGS file contained:

```
'GENERIC TRAINER AIRCRAFT - CSC/NASA/LARC, 5/88'
'WING - UPPER AND LOWER SURFACES, PORT SIDE'
1 5 10 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 1
260. 0. -14. 43.5 0. -28. -65. 0. -19. -119. 0. -11.5 -173. 0. 9.
-173. 0. 11. -119. 0. 34. -65. 0. 38.5 43.5 0. 33. 260. 0. -12.
227. 198. 12. 76. 198. 1. 0. 198. 4. -38. 198. 9. -76. 198. 28.
-76. 198. 30. -38. 198. 53. 0. 198. 55. 76. 198. 46. 227. 198. 14.
181.5 477. 48.5 60.5 477. 41.5 0. 477. 44. -30. 477. 48. -60.5 477. 62.
-60.5 477. 64. -30. 477. 80. 0. 477. 81. 60.5 477. 74. 181.5 477. 50.5
136. 756. 85. 45. 756. 82. 0. 756. 84. -22.5 756. 87. -45. 756. 96.
-45. 756. 98. -22.5 756. 107. 0. 756. 107. 45. 756. 102. 136. 756. 87.
136. 756. 86. 45. 756. 92. 0. 756. 95.5 -22.5 756. 92.5 -45. 756. 97.
-45. 756. 97. -22.5 756. 92.5 0. 756. 95.5 45. 756. 92. 136. 756. 86.
```

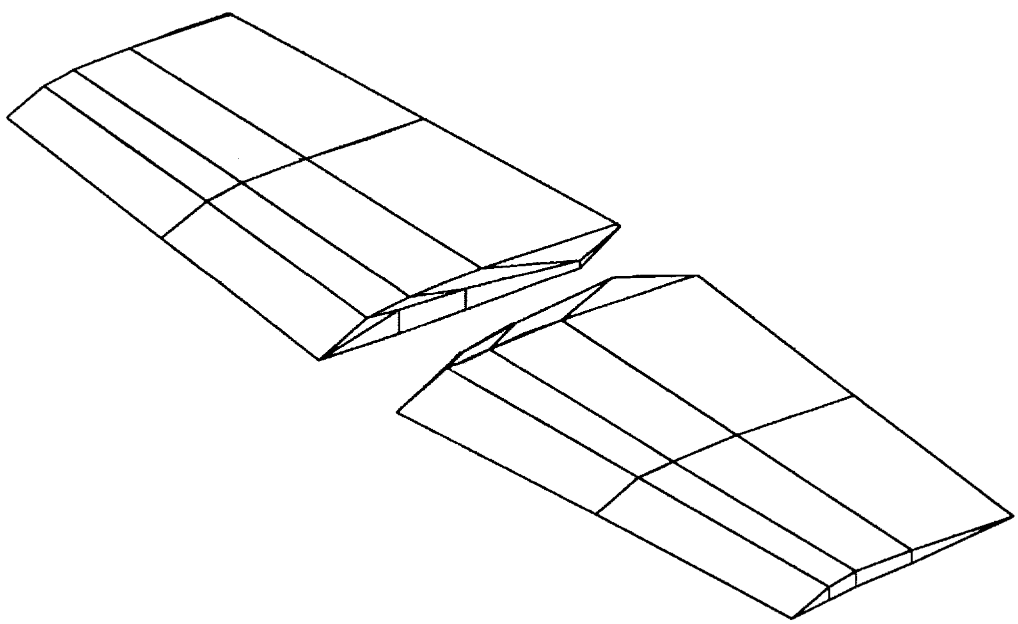
The resulting LaWGS component looked like:



Three cross sections were available for the horizontal stabilizer, of which two were selected and three more derived. Five points per cross section were used, at 0%, 20.5%, 55.6%, 75.4%, and 100% chord (this unusual distribution appeared to best retain the stabilizer's leading edge shape). Like the wing, the Y-axis was dominant -- only the (x,z) coordinates were recorded, and a constant Y value for each cross section was later added. Also, like the wing, a sixth cross section was created at the stabilizer's outboard tip, approximating the mean camber line, serving to "close off" the open edge. The resulting raw LaWGS file contained:

```
'GENERIC TRAINER AIRCRAFT - CSC/NASA/LARC, 5/88'
'STABILIZER - UPPER SURFACE, PORT SIDE'
1 6 5 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 1
88. 29. .3 48. 12. .3 -20.5 20. .3 -59. 25. .3 -107. 31. .3
88. 29. .3 48. 12. 5. -20.5 20. 11. -59. 25. 12. -107. 31. .3
88. 31. .3 0. 31. 10. -47. 31. 12. -74. 31. 11. -107. 31. .3
76.5 167.5 .3 0. 167.5 8.5 -41.5 167.5 10.5 -64.5 167.5 9.5 -93.5 167.5 .3
65. 304. .3 0. 304. 7. -36. 304. 9. -55. 304. 8. -79.5 304. .3
65. 304. .3 0. 304. .3 -36. 304. .3 -55. 304. .3 -79.5 304. .3
```

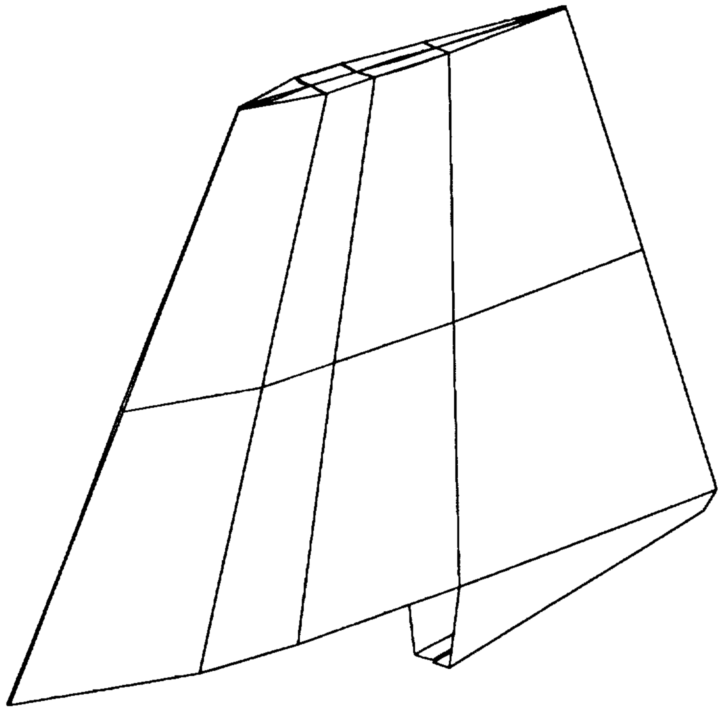
The resulting raw LaWGS component looked like:



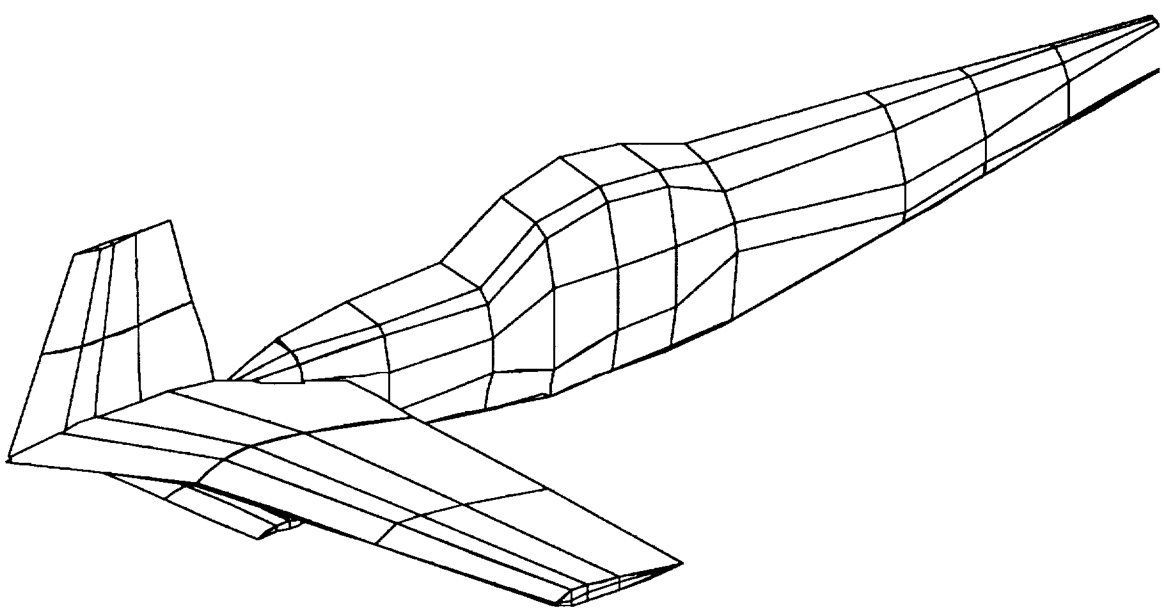
Three cross sections were available for the vertical tail, of which CSC selected three for the upper section and derived two for the lower. Five points per cross section were used for the upper section, at 0%, 21.6%, 36%, 60%, and 100% chord (which preserved the tail's leading edge shape). Because the Z-axis was dominant, only the (x,y) coordinates were recorded. A constant Z value for each cross section was later added. Three cross sections using two points each were used to describe the tail's lower section. The resulting raw LaWGS file contained:

```
'GENERIC TRAINER AIRCRAFT - CSC/NASA/LARC, 5/88'
'VERTICAL TAIL - UPPER SECTION, PORT SIDE'
1 4 5 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 1
-172. .3 16. -110. 17. 16. -69. 17. 16. 0. 13. 16. 115. .3 16.
-126. .3 144. -80.5 12.5 144. -50.5 12.5 144. 0. 9.5 144. 84. .3 144.
-80. .3 272. -51. 8. 272. -32. 8. 272. 0. 6. 272. 53. .3 272.
-80. 0. 272. -51. 0. 272. -32. 0. 272. 0. 0. 272. 53. 0. 272.
'VERTICAL TAIL - LOWER SECTION, PORT SIDE'
1 3 2 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 1
0. 13. 16. 115. 0. 16.
0. 8. -26. 110. 0. 8.
0. 0. -26. 110. 0. 8.
```

The resulting raw LaWGS component looked like:



The wing, horizontal stabilizer, and vertical tail components were digitized in their respective local coordinate systems. Without adjusting them to a common (global) axis system, the aircraft appeared:



CSC corrected the geometry by manipulating the affected LaWGS components' control headers, rather than by manipulating the (x,y,z) corrdinate data. In this case, the wing's local origin was at global (630,0,0), the horizontal stabilizer's at (1399,0,0), and the vertical tail's at (1430,0,0). CSC changed the wing, stabilizer, and tail component control headers as follows:

```
Forebody
        from   1 6 9 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 0
        to     1 6 9 0 0. 0. 0. 0. 0. 0. 7. 7. 7. 1

Midbody
        from   1 5 6 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 0
        to     1 5 6 0 0. 0. 0. 0. 0. 0. 7. 7. 7. 1

Aftbody
        from   1 5 9 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 0
        to     1 5 9 0 0. 0. 0. 0. 0. 0. 7. 7. 7. 1

Canopy
        from   1 5 4 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 0
        to     1 5 4 0 0. 0. 0. 0. 0. 0. 7. 7. 7. 1

Wing
        from   1 4 9 0 0. 0. 0.   0. 0. 0. 1. 1. 1. 0
        to     1 4 9 0 0. 0. 0. 630. 0. 0. 7. 7. 7. 1

Stabilizer
        from   1 5 5 0 0. 0. 0.    0. 0. 0. 1. 1. 1. 0
        to     1 5 5 2 0. 0. 0. 1399. 0. 0. 7. 7. 7. 1

Tail - upper
        from   1 4 5 0 0. 0. 0.    0. 0. 0. 1. 1. 1. 0
        to     1 4 5 0 0. 0. 0. 1430. 0. 0. 7. 7. 7. 1

Tail - lower
        from   1 3 2 0 0. 0. 0.    0. 0. 0. 1. 1. 1. 0
        to     1 3 2 0 0. 0. 0. 1430. 0. 0. 7. 7. 7. 1
```

After the requested scale factors and tranlsations were applied, and after the appropriate symmetry indicators were added, the final LaWGS file contained:

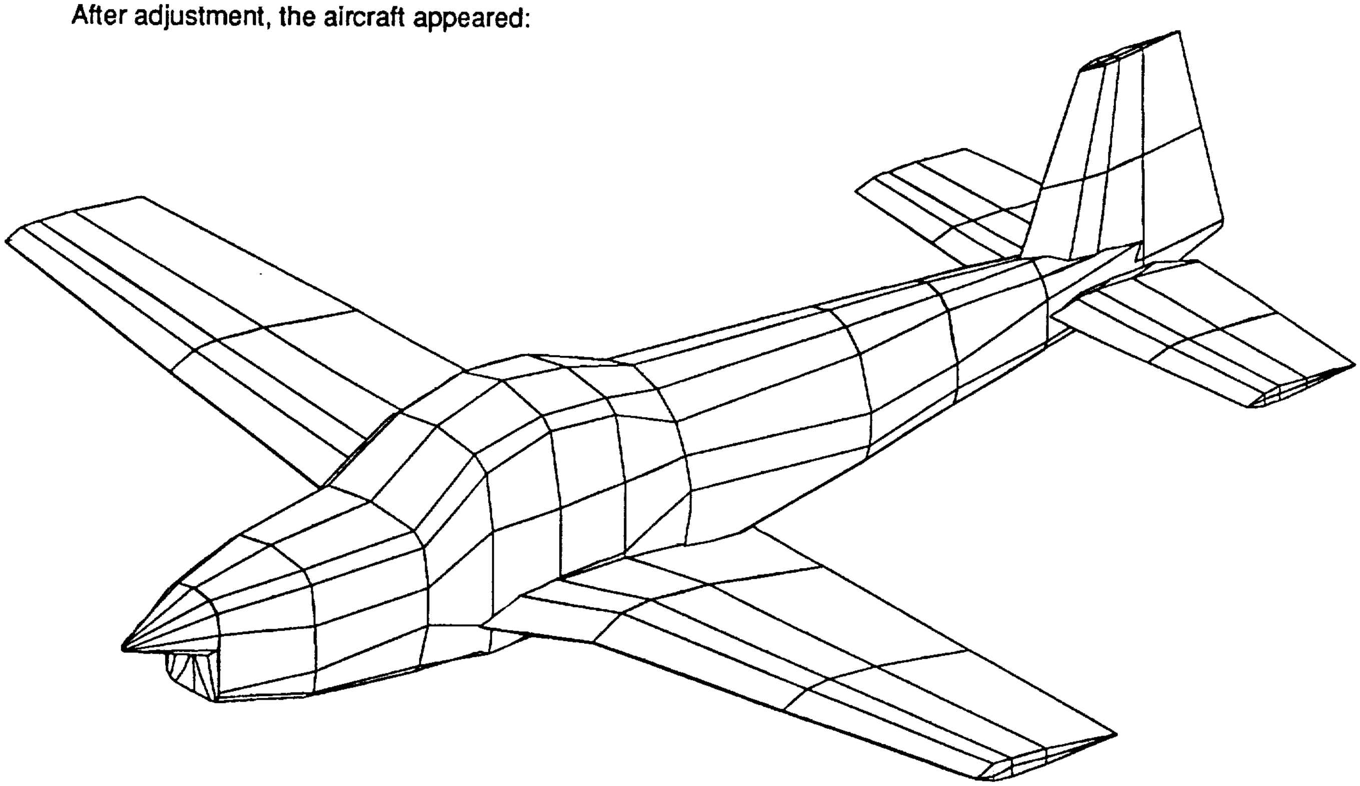
```
'GENERIC TRAINER AIRCRAFT - CSC/NASA/LARC, 5/88                                  '
'FOREBODY FUSELAGE, PORT SIDE                                                    '
 1 6 9 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 1
   .76300E+03   .00000E+00   .00000E+00   .76300E+03   .00000E+00   .00000E+00
   .76300E+03   .00000E+00   .00000E+00   .76300E+03   .00000E+00   .00000E+00
   .76300E+03   .00000E+00   .00000E+00   .76300E+03   .00000E+00   .00000E+00
   .76300E+03   .00000E+00   .00000E+00   .76300E+03   .00000E+00   .00000E+00
   .76300E+03   .00000E+00   .00000E+00   .77700E+03   .00000E+00  -.21000E+02
   .77700E+03   .00000E+00  -.21000E+02   .77700E+03   .14000E+02  -.17500E+02
   .77700E+03   .24500E+02  -.70000E+01   .77700E+03   .28000E+02   .70000E+01
   .77700E+03   .28000E+02   .70000E+01   .77700E+03   .24500E+02   .70000E+01
   .77700E+03   .14000E+02   .31500E+02   .77700E+03   .00000E+00   .35000E+02
   .14000E+04   .00000E+00  -.25200E+03   .14000E+04   .00000E+00  -.25200E+03
   .14000E+04   .15400E+03  -.21000E+03   .14000E+04   .26600E+03  -.11200E+03
   .14000E+04   .29400E+03   .28000E+02   .14000E+04   .29400E+03   .28000E+02
   .14000E+04   .25900E+03   .18900E+03   .14000E+04   .16800E+03   .28000E+03
   .14000E+04   .00000E+00   .31500E+03   .14070E+04   .00000E+00  -.60200E+03
```

```
   .14070E+04   .18200E+03  -.60200E+03   .14070E+04   .23800E+03  -.58100E+03
   .14070E+04   .28000E+03  -.53900E+03   .14070E+04   .29400E+03  -.49000E+03
   .14070E+04   .29400E+03   .28000E+02   .14070E+04   .25900E+03   .18900E+03
   .14070E+04   .16800E+03   .28000E+03   .14070E+04   .00000E+00   .31500E+03
   .21000E+04   .00000E+00  -.77700E+03   .21000E+04   .19600E+03  -.77000E+03
   .21000E+04   .38500E+03  -.73500E+03   .21000E+04   .46900E+03  -.65100E+03
   .21000E+04   .50400E+03  -.44800E+03   .21000E+04   .49000E+03  -.63000E+02
   .21000E+04   .43400E+03   .28000E+03   .21000E+04   .35000E+03   .36400E+03
   .21000E+04   .00000E+00   .42700E+03   .30030E+04   .00000E+00  -.85400E+03
   .30030E+04   .19600E+03  -.85400E+03   .30030E+04   .47600E+03  -.79100E+03
   .30030E+04   .53900E+03  -.72800E+03   .30030E+04   .61600E+03  -.32900E+03
   .30030E+04   .61600E+03   .00000E+00   .30030E+04   .56700E+03   .32200E+03
   .30030E+04   .46200E+03   .42700E+03   .30030E+04   .00000E+00   .49000E+03
'MIDBODY FUSELAGE, PORT SIDE                                                  '
 1 5 6 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 1
   .30030E+04   .00000E+00  -.85400E+03   .30030E+04   .19600E+03  -.85400E+03
   .30030E+04   .47600E+03  -.79100E+03   .30030E+04   .53900E+03  -.72800E+03
   .30030E+04   .61600E+03  -.32900E+03   .30030E+04   .61600E+03   .00000E+00
   .35980E+04   .00000E+00  -.88200E+03   .35980E+04   .32200E+03  -.86800E+03
   .35980E+04   .49700E+03  -.82600E+03   .35980E+04   .58800E+03  -.81200E+03
   .35980E+04   .63000E+03  -.53900E+03   .35980E+04   .63000E+03   .28000E+03
   .42000E+04   .00000E+00  -.89600E+03   .42000E+04   .28700E+03  -.88900E+03
   .42000E+04   .52500E+03  -.83300E+03   .42000E+04   .59500E+03  -.76300E+03
   .42000E+04   .65100E+03  -.32900E+03   .42000E+04   .65100E+03   .28000E+03
   .47950E+04   .00000E+00  -.88900E+03   .47950E+04   .30100E+03  -.88200E+03
   .47950E+04   .51100E+03  -.82600E+03   .47950E+04   .58100E+03  -.76300E+03
   .47950E+04   .65100E+03  -.32900E+03   .47950E+04   .64400E+03   .28000E+03
   .53970E+04   .00000E+00  -.85400E+03   .53970E+04   .11900E+03  -.85400E+03
   .53970E+04   .49700E+03  -.79100E+03   .53970E+04   .58100E+03  -.70700E+03
   .53970E+04   .65100E+03   .00000E+00   .53970E+04   .59500E+03   .28000E+03
'AFTBODY FUSELAGE, PORT SIDE                                                  '
 1 5 9 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 1
   .53970E+04   .00000E+00  -.85400E+03   .53970E+04   .11900E+03  -.85400E+03
   .53970E+04   .49700E+03  -.79100E+03   .53970E+04   .58100E+03  -.70700E+03
   .53970E+04   .65100E+03   .00000E+00   .53970E+04   .59500E+03   .28000E+03
   .53970E+04   .47600E+03   .53200E+03   .53970E+04   .28000E+03   .73500E+03
   .53970E+04   .00000E+00   .81200E+03   .72030E+04   .00000E+00  -.60900E+03
   .72030E+04   .70000E+02  -.60900E+03   .72030E+04   .35000E+03  -.55300E+03
   .72030E+04   .42000E+03  -.48300E+03   .72030E+04   .46200E+03  -.35000E+03
   .72030E+04   .46200E+03  -.63000E+02   .72030E+04   .34300E+03   .40600E+03
   .72030E+04   .19600E+03   .58100E+03   .72030E+04   .00000E+00   .63000E+03
   .80990E+04   .00000E+00  -.46900E+03   .80990E+04   .10500E+03  -.46900E+03
   .80990E+04   .25200E+03  -.43400E+03   .80990E+04   .30800E+03  -.37800E+03
   .80990E+04   .34300E+03  -.22400E+03   .80990E+04   .34300E+03   .00000E+00
   .80990E+04   .23800E+03   .40600E+03   .80990E+04   .14000E+03   .50400E+03
   .80990E+04   .00000E+00   .54600E+03   .90020E+04   .00000E+00  -.33600E+03
   .90020E+04   .56000E+02  -.33250E+03   .90020E+04   .14000E+03  -.32200E+03
   .90020E+04   .20300E+03  -.26600E+03   .90020E+04   .22400E+03  -.18900E+03
   .90020E+04   .22400E+03   .16800E+03   .90020E+04   .16800E+03   .34300E+03
   .90020E+04   .63000E+02   .44800E+03   .90020E+04   .00000E+00   .45500E+03
   .10010E+05   .00000E+00  -.18200E+03   .10010E+05   .42000E+02  -.17500E+03
   .10010E+05   .63000E+02  -.16800E+03   .10010E+05   .80500E+02  -.15050E+03
   .10010E+05   .84000E+02  -.11900E+03   .10010E+05   .84000E+02   .28000E+03
   .10010E+05   .70000E+02   .32200E+03   .10010E+05   .28000E+02   .35000E+03
   .10010E+05   .00000E+00   .35700E+03
'CANOPY - PORT SIDE                                                           '
 1 5 4 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 1
   .30030E+04   .00000E+00   .49000E+03   .30030E+04   .46200E+03   .42700E+03
```

```
   .30030E+04   .56700E+03   .32200E+03   .30030E+04   .61600E+03   .00000E+00
   .35980E+04   .00000E+00   .93100E+03   .35980E+04   .41300E+03   .86800E+03
   .35980E+04   .53900E+03   .75600E+03   .35980E+04   .63000E+03   .28000E+03
   .42000E+04   .00000E+00   .11130E+04   .42000E+04   .44100E+03   .99400E+03
   .42000E+04   .53200E+03   .90300E+03   .42000E+04   .65100E+03   .28000E+03
   .47950E+04   .00000E+00   .10080E+04   .47950E+04   .43400E+03   .93800E+03
   .47950E+04   .53900E+03   .83300E+03   .47950E+04   .64400E+03   .28000E+03
   .53970E+04   .00000E+00   .81200E+03   .53970E+04   .28000E+03   .73500E+03
   .53970E+04   .47600E+03   .53200E+03   .53970E+04   .59500E+03   .28000E+03
'WING - UPPER AND LOWER SURFACES, PORT SIDE                                      '
 1 5 10 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 1
   .62310E+04   .00000E+00  -.75800E+03   .47155E+04   .00000E+00  -.85600E+03
   .39560E+04   .00000E+00  -.79300E+03   .35780E+04   .00000E+00  -.74050E+03
   .32000E+04   .00000E+00  -.59700E+03   .32000E+04   .00000E+00  -.58300E+03
   .35780E+04   .00000E+00  -.42200E+03   .39560E+04   .00000E+00  -.39050E+03
   .47155E+04   .00000E+00  -.42900E+03   .62310E+04   .00000E+00  -.74400E+03
   .60000E+04   .13860E+04  -.57600E+03   .49430E+04   .13860E+04  -.65300E+03
   .44110E+04   .13860E+04  -.63200E+03   .41450E+04   .13860E+04  -.59700E+03
   .38790E+04   .13860E+04  -.46400E+03   .38790E+04   .13860E+04  -.45000E+03
   .41450E+04   .13860E+04  -.28900E+03   .44110E+04   .13860E+04  -.27500E+03
   .49430E+04   .13860E+04  -.33800E+03   .60000E+04   .13860E+04  -.56200E+03
   .56815E+04   .33390E+04  -.32050E+03   .48345E+04   .33390E+04  -.36950E+03
   .44110E+04   .33390E+04  -.35200E+03   .42010E+04   .33390E+04  -.32400E+03
   .39875E+04   .33390E+04  -.22600E+03   .39875E+04   .33390E+04  -.21200E+03
   .42010E+04   .33390E+04  -.10000E+03   .44110E+04   .33390E+04  -.93000E+02
   .48345E+04   .33390E+04  -.14200E+03   .56815E+04   .33390E+04  -.30650E+03
   .53630E+04   .52920E+04  -.65000E+02   .47260E+04   .52920E+04  -.86000E+02
   .44110E+04   .52920E+04  -.72000E+02   .42535E+04   .52920E+04  -.51000E+02
   .40960E+04   .52920E+04   .12000E+02   .40960E+04   .52920E+04   .26000E+02
   .42535E+04   .52920E+04   .89000E+02   .44110E+04   .52920E+04   .89000E+02
   .47260E+04   .52920E+04   .54000E+02   .53630E+04   .52920E+04  -.51000E+02
   .53630E+04   .52920E+04  -.58000E+02   .47260E+04   .52920E+04  -.16000E+02
   .44110E+04   .52920E+04   .85000E+01   .42535E+04   .52920E+04  -.12500E+02
   .40960E+04   .52920E+04   .19000E+02   .40960E+04   .52920E+04   .19000E+02
   .42535E+04   .52920E+04  -.12500E+02   .44110E+04   .52920E+04   .85000E+01
   .47260E+04   .52920E+04  -.16000E+02   .53630E+04   .52920E+04  -.58000E+02
'STABILIZER - UPPER SURFACE, PORT SIDE                                          '
 1 6 5 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 1
   .10408E+05   .20300E+03   .21000E+01   .10128E+05   .84000E+02   .21000E+01
   .96485E+04   .14000E+03   .21000E+01   .93790E+04   .17500E+03   .21000E+01
   .90430E+04   .21700E+03   .21000E+01   .10408E+05   .20300E+03   .21000E+01
   .10128E+05   .84000E+02   .35000E+02   .96485E+04   .14000E+03   .77000E+02
   .93790E+04   .17500E+03   .84000E+02   .90430E+04   .21700E+03   .21000E+01
   .10408E+05   .21700E+03   .21000E+01   .97920E+04   .21700E+03   .70000E+02
   .94630E+04   .21700E+03   .84000E+02   .92740E+04   .21700E+03   .77000E+02
   .90430E+04   .21700E+03   .21000E+01   .10328E+05   .11725E+04   .21000E+01
   .97920E+04   .11725E+04   .59500E+02   .95015E+04   .11725E+04   .73500E+02
   .93405E+04   .11725E+04   .66500E+02   .91375E+04   .11725E+04   .21000E+01
   .10247E+05   .21280E+04   .21000E+01   .97920E+04   .21280E+04   .49000E+02
   .95400E+04   .21280E+04   .63000E+02   .94070E+04   .21280E+04   .56000E+02
   .92355E+04   .21280E+04   .21000E+01   .10247E+05   .21280E+04   .21000E+01
   .97920E+04   .21280E+04   .21000E+01   .95400E+04   .21280E+04   .21000E+01
   .94070E+04   .21280E+04   .21000E+01   .92355E+04   .21280E+04   .21000E+01
'STABILIZER - UPPER SURFACE, PORT SIDE - IMAGE #1                               '
 1 6 5 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 1
   .10408E+05   .20300E+03  -.21000E+01   .10128E+05   .84000E+02  -.21000E+01
   .96485E+04   .14000E+03  -.21000E+01   .93790E+04   .17500E+03  -.21000E+01
   .90430E+04   .21700E+03  -.21000E+01   .10408E+05   .20300E+03  -.21000E+01
```

```
   .10128E+05   .84000E+02  -.35000E+02   .96485E+04   .14000E+03  -.77000E+02
   .93790E+04   .17500E+03  -.84000E+02   .90430E+04   .21700E+03  -.21000E+01
   .10408E+05   .21700E+03  -.21000E+01   .97920E+04   .21700E+03  -.70000E+02
   .94630E+04   .21700E+03  -.84000E+02   .92740E+04   .21700E+03  -.77000E+02
   .90430E+04   .21700E+03  -.21000E+01   .10328E+05   .11725E+04  -.21000E+01
   .97920E+04   .11725E+04  -.59500E+02   .95015E+04   .11725E+04  -.73500E+02
   .93405E+04   .11725E+04  -.66500E+02   .91375E+04   .11725E+04  -.21000E+01
   .10247E+05   .21280E+04  -.21000E+01   .97920E+04   .21280E+04  -.49000E+02
   .95400E+04   .21280E+04  -.63000E+02   .94070E+04   .21280E+04  -.56000E+02
   .92355E+04   .21280E+04  -.21000E+01   .10247E+05   .21280E+04  -.21000E+01
   .97920E+04   .21280E+04  -.21000E+01   .95400E+04   .21280E+04  -.21000E+01
   .94070E+04   .21280E+04  -.21000E+01   .92355E+04   .21280E+04  -.21000E+01
'VERTICAL TAIL - UPPER SECTION, PORT SIDE                                        '
 1 4 5 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 1
   .88080E+04   .21000E+01   .11200E+03   .92420E+04   .11900E+03   .11200E+03
   .95290E+04   .11900E+03   .11200E+03   .10012E+05   .91000E+02   .11200E+03
   .10817E+05   .21000E+01   .11200E+03   .91300E+04   .21000E+01   .10080E+04
   .94485E+04   .87500E+02   .10080E+04   .96585E+04   .87500E+02   .10080E+04
   .10012E+05   .66500E+02   .10080E+04   .10600E+05   .21000E+01   .10080E+04
   .94520E+04   .21000E+01   .19040E+04   .96550E+04   .56000E+02   .19040E+04
   .97880E+04   .56000E+02   .19040E+04   .10012E+05   .42000E+02   .19040E+04
   .10383E+05   .21000E+01   .19040E+04   .94520E+04   .21000E+01   .19040E+04
   .96550E+04   .21000E+01   .19040E+04   .97880E+04   .21000E+01   .19040E+04
   .10012E+05   .21000E+01   .19040E+04   .10383E+05   .21000E+01   .19040E+04
'VERTICAL TAIL - LOWER SECTION, PORT SIDE                                        '
 1 3 2 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 1
   .10012E+05   .91000E+02   .11200E+03   .10817E+05   .21000E+01   .11200E+03
   .10012E+05   .56000E+02  -.18200E+03   .10782E+05   .21000E+01   .56000E+02
   .10012E+05   .21000E+01  -.18200E+03   .10782E+05   .21000E+01   .56000E+02
```

After adjustment, the aircraft appeared:

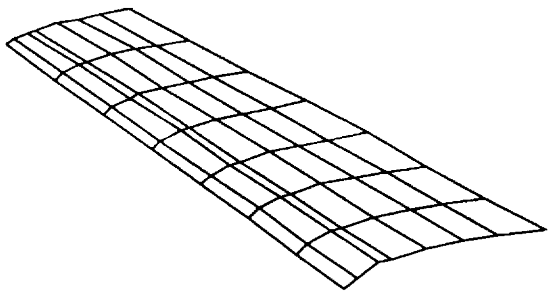


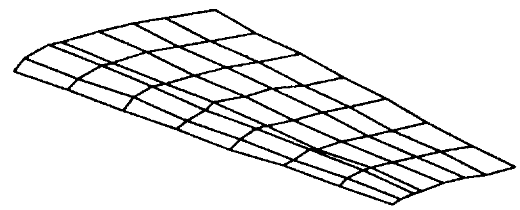
The aircraft geometry LaWGS file was then complete.

CSC was provided with a rough drawing showing the locations of all of the pressure ports on the wing. There were eight spanwise "strips" of ports, and their Y-axis locations were indicated. Virtually none of the span locations corresponded with any wing spar location (it is, after all, nearly impossible to drill and instrument a pressure port within a wing spar). Each strip contained eight pressure ports, at 5, 10, 20, 25, 40, 55, 70, and 90% chord locations. The Y-axis coordinates were known from the spanwise location. The X-axis coordinates were derived by interpolation between the two surrounding wing cross sections (taking into account that chord length and leading edge location varied between two adjacent wing cross sections). The Z-axis coordinates were derived similarly, interpolating the elevations at the same % chord locations at the two adjoining cross sections. The result was an 8x8 mesh of pressure ports. The associated LaWGS file looked like:

```
'GENERIC TRAINER AIRCRAFT - CSC/NASA/LARC, 5/88                                '
'WING (UPPER SURFACE) PRESSURE PORTS, PORT SIDE                                '
 1 8 8 0 0. 0. 0. 0. 0. 0. 1. 1. 1. 0
   .39847E+04   .13860E+04  -.37770E+03   .40911E+04   .13860E+04  -.31440E+03
   .43032E+04   .13860E+04  -.26890E+03   .44110E+04   .13860E+04  -.27490E+03
   .47274E+04   .13860E+04  -.30380E+03   .50459E+04   .13860E+04  -.35760E+03
   .53630E+04   .13860E+04  -.42350E+03   .57900E+04   .13860E+04  -.51670E+03
   .40071E+04   .19250E+04  -.31770E+03   .41072E+04   .19250E+04  -.25960E+03
   .43074E+04   .19250E+04  -.21840E+03   .44110E+04   .19250E+04  -.22420E+03
   .47078E+04   .19250E+04  -.25180E+03   .50081E+04   .19250E+04  -.30180E+03
   .53070E+04   .19250E+04  -.36290E+03   .57060E+04   .19250E+04  -.44940E+03
   .40358E+04   .24710E+04  -.25700E+03   .41303E+04   .24710E+04  -.20410E+03
   .43186E+04   .24710E+04  -.16730E+03   .44110E+04   .24710E+04  -.17290E+03
   .46952E+04   .24710E+04  -.19910E+03   .49780E+04   .24710E+04  -.24520E+03
   .52580E+04   .24710E+04  -.30150E+03   .56360E+04   .24710E+04  -.38120E+03
   .40582E+04   .30100E+04  -.19700E+03   .41464E+04   .30100E+04  -.14930E+03
   .43228E+04   .30100E+04  -.11690E+03   .44110E+04   .30100E+04  -.12220E+03
   .46756E+04   .30100E+04  -.14710E+03   .49402E+04   .30100E+04  -.18930E+03
   .52020E+04   .30100E+04  -.24100E+03   .55590E+04   .30100E+04  -.31380E+03
   .40799E+04   .35560E+04  -.13630E+03   .41625E+04   .35560E+04  -.93810E+02
   .43270E+04   .35560E+04  -.65770E+02   .44110E+04   .35560E+04  -.70920E+02
   .46560E+04   .35560E+04  -.94450E+02   .49031E+04   .35560E+04  -.13280E+03
   .51530E+04   .35560E+04  -.17960E+03   .54820E+04   .35560E+04  -.24560E+03
   .41023E+04   .40950E+04  -.76330E+02   .41786E+04   .40950E+04  -.39020E+02
   .43312E+04   .40950E+04  -.15320E+02   .44110E+04   .40950E+04  -.20250E+02
   .46364E+04   .40950E+04  -.42450E+02   .48653E+04   .40950E+04  -.76920E+02
   .50942E+04   .40950E+04  -.11900E+03   .53980E+04   .40950E+04  -.17830E+03
   .41310E+04   .46410E+04  -.15600E+02   .42017E+04   .46410E+04   .16480E+02
   .43424E+04   .46410E+04   .35800E+02   .44110E+04   .46410E+04   .31070E+02
   .46238E+04   .46410E+04   .10220E+02   .48352E+04   .46410E+04  -.20350E+02
   .50459E+04   .46410E+04  -.57640E+02   .53280E+04   .46410E+04  -.11010E+03
   .41534E+04   .51800E+04   .44370E+02   .42178E+04   .51800E+04   .71270E+02
   .43466E+04   .51800E+04   .86250E+02   .44110E+04   .51800E+04   .81740E+02
   .46042E+04   .51800E+04   .62220E+02   .47974E+04   .51800E+04   .35500E+02
   .49906E+04   .51800E+04   .29410E+02   .52510E+04   .51800E+04  -.42770E+02
```

Geometrically, the pressure port distribution appeared:





which looked like the wing's upper surface, as it should.

Like the wing component in the aircraft geometry LaWGS file, the pressure port locations were relative to the wing's local axis system. CSC changed the pressure ports' component control header:

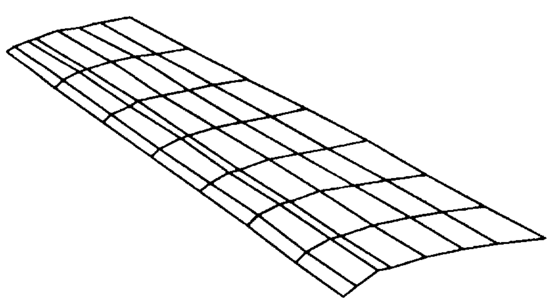
from:

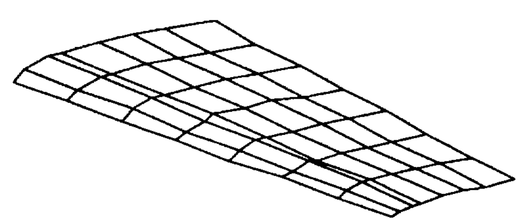
```
1 8 8 0 0. 0. 0.    0. 0. 0. 1. 1. 1. 0
```

to:

```
1 8 8 0 0. 0. 0. 630. 0. 0. 7. 7. 7. 0
```

When displayed graphically, the pressure port LaWGS file still appears as:





which was expected. However, the shift to global coordinates aligned the pressure ports with the aircraft's wing, already in global space. The pressure port LaWGS file was then complete.

Next, the pressure port ID sequence was prepared. This step is performed because, as a rule, raw pressure data is associated with only the pressure port's ID, not its (x,y,z) location. In this example, the raw data files took the form:

```
12/15/87      MK-1                     BWHV UPPER LEFT WING       1.000E+00
-1.2352-1.6590    1    91     1    40 .0000    5    0
-1.2181-1.6359    2    92     2    40 .0000    5    0
 -.9609-1.2905    3    94     3    40 .0000    5    0
 -.9219-1.2382    4    95     4    40 .0000    5    0
 -.5115 -.6870    5    96     5    40 .0000    5    0
 -.3632 -.4878    6    97     6    40 .0000    5    0
 .
 .
 .
```

(The raw pressure data and the corresponding port ID have been highlighted in **bold** print.)

Looking at the first pressure port geometry "slice" (at y=1386):

```
.39847E+04   .13860E+04  -.37770E+03   .40911E+04   .13860E+04  -.31440E+03
.43032E+04   .13860E+04  -.26890E+03   .44110E+04   .13860E+04  -.27490E+03
.47274E+04   .13860E+04  -.30380E+03   .50459E+04   .13860E+04  -.35760E+03
.53630E+04   .13860E+04  -.42350E+03   .57900E+04   .13860E+04  -.51670E+03
```

there were eight locations which, according to the pressure port plans, were labeled ports 31, 32, 34, 35, 36, 37, 38, and 40, in that order. Similarly, the second slice (at y=1925) were labeled ports 61, 62, 64, 65, 66, 67, 68, and 70. The following table summarizes the ports ID's used at each spanwise location:

Slice	Constant Y	Pressure Port ID's
1	1386	31, 32, 34-38, 40
2	1925	61, 62, 64-68, 70
3	2417	91, 92, 94-98, 100
4	3010	121, 122, 124-128, 130
5	3556	151, 152, 154-158, 160
6	4095	181, 182, 184-188, 190
7	4641	211, 212, 214-218, 220
8	5180	241, 242, 244-248, 250

From this table, the corresponding pressure port ID sequence file was developed:

```
64
31
32
34
35
36
37
38
40
61
62
64
```

```
65
66
67
68
70
91
92
94
95
96
97
98
100
121
122
124
125
126
127
128
130
151
152
154
155
156
157
158
160
181
182
184
185
186
187
188
190
211
212
214
215
216
217
218
220
241
242
244
245
246
247
248
250
```

Program G2TOAD was then executed to create the TOAD file containing the necessary displacement vector information:

```
---------------------------------------------

     Pressure Visualization Package (PreViz)

          Module G2TOAD       Release 1.0

---------------------------------------------



     What is the name of the LaWGS file containing the
     pressure port locations ?
> ppgeom

     What is the name of the file containing the pressure port
     ID sequence ?
> ppseq

     What is the name of the new TOAD file being created ?
> pptoad



     Normal run.
```

CSC noted that all of the wind tunnel raw data files used the same format, and changed program D2TOAD accordingly. Specifically, the FORMAT statement (line 68) was changed to:

```
      1100 FORMAT(F7.4,T20,I5)
```

Program D2TOAD was then compiled, loaded, and executed to convert a wind tunnel raw data file into a TOAD file:

```
---------------------------------------------

     Pressure Visualization Package (PreViz)

          Module D2TOAD       Release 1.0

---------------------------------------------



     What is the name of the raw data file to be read ?
> raw1

     What is the name of the new TOAD file being created ?
> rtoad1
```

```
Normal run.
```

Because many raw data files were to be analyzed, program D2TOAD was executed many times. Every available wind tunnel raw data file was converted into a TOAD file:

Raw Data Set #1	→	**D2TOAD**	→	*Raw TOAD File #1*
Raw Data Set #2	→	**D2TOAD**	→	*Raw TOAD File #2*
.		.		.
.		.		.
Raw Data Set #n	→	**D2TOAD**	→	*Raw TOAD File #n*

Executing program T2GEOM is the last step in the PreViz sequence. After reviewing the raw data to be displayed, and considering the aircraft size, CSC selected a maximum C_p magnitude of 2.0, with a corresponding maximum displacement vector length of 500 units. Thus, a C_p of 2.0 created a displacement vector of 500mm, a C_p of 1.0 created one of 250mm, and so on. This was implemented in program T2GEOM by editing block data PRESET and changing two DATA statements to appear:

```
DATA RMXDIS             / 500. /
DATA RMXMAG             / 2.   /
```

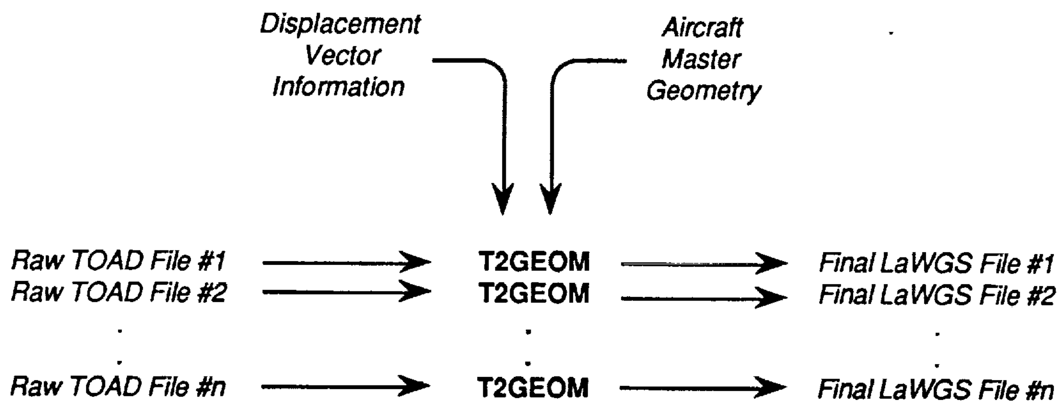
(The vector's arrowhead size and shape are controlled by variables SHAFT, HEADL, and HEADW, all in subroutine VECTOR.)

Program T2GEOM was then compiled, loaded, and executed:

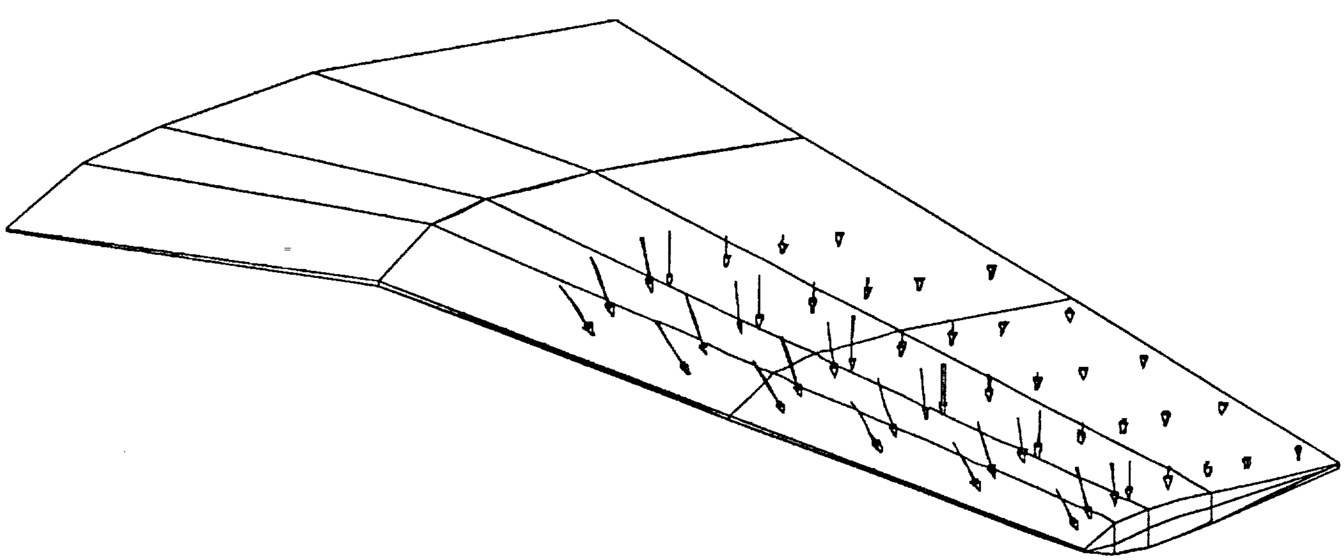
```
     -------------------------------------------

       Pressure Visualization Package (PreViz)

           Module T2GEOM       Release 1.0

     -------------------------------------------


    What is the name of the TOAD file containing the pressure
    displacement vector's direction cosines ?
> pptoad

    What is the name of the TOAD file containing the refined
    pressure data ?
> rtoad1

    What is the name of the LaWGS file containing the master
    aircraft geometry ?
> trainer
```

```
     What is the name of the new LaWGS file being created ?
> geoml


     Normal run.
```

Like program D2TOAD, because many raw data files were to be analyzed, program T2GEOM was executed many times. Every TOAD file created via D2TOAD was transformed and merged with the aircraft master geometry file:



Finally, CSC used the Cockpit Oriented Display of Aircraft Configurations (CODAC) to view these final LaWGS files. The following is a sample image produced using CODAC:



Appendix B
The LaWGS Format (summarized)

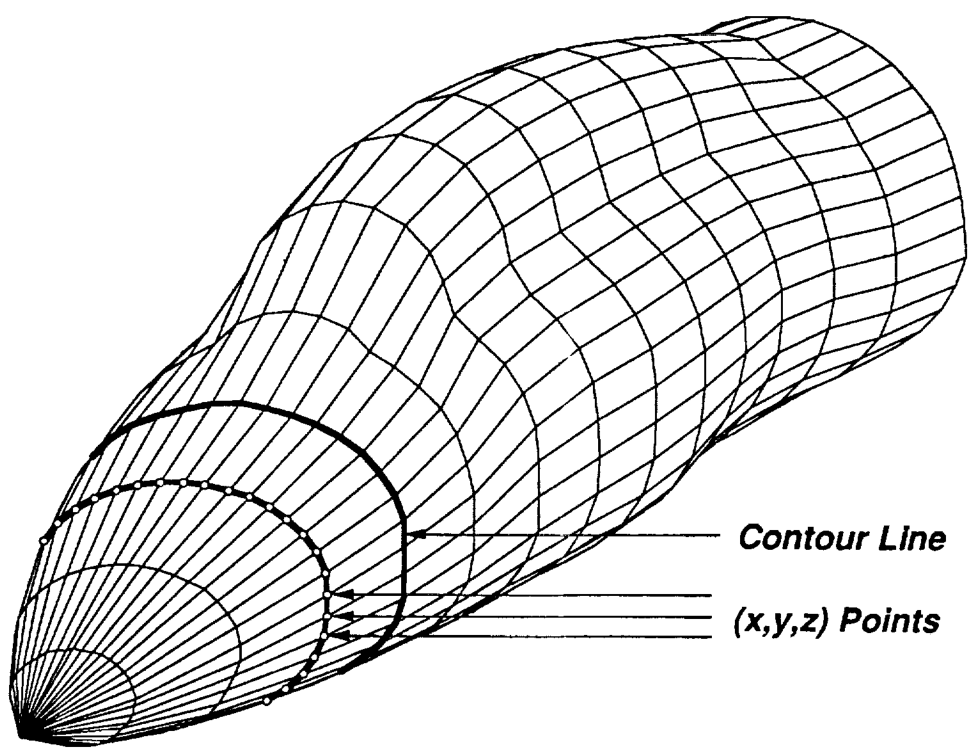
The Langley Wireframe Geometry Standard (LaWGS) format was developed by NASA Langley Research Center as a uniform way to describe three-dimensional objects. A full discussion of the LaWGS format is presented in NASA Technical Memorandum 85767. However, most readers will find the following abbreviated description adequate for their purposes.

A single LaWGS file generally describes an entire *configuration*, usually defined as a set of *components*. For example, a file may describe an aircraft *configuration* as a collection of fuselage, canopy, wing, and control surface *components*. LaWGS places no limit on the number of components per configuration.

Each *component* is defined as a series of *contour lines*. For example, a wing *component* may be defined as a collection of cross-sectional airfoil *contour lines* at an ordered sequence of span locations. There are two categories of contour lines: closed and open. Closed contour lines have both ends at the same location. For example, the cross-sectional contour line of a full fuselage would be closed. Open contour lines have their ends at different locations. For example, a wing's upper surface contour, starting from the leading edge and ending at the trailing edge, would be an open contour line. LaWGS permits either type, or a mixture of both, within each component. However, LaWGS allows no more than 50 contour lines per component.

Each *contour line* is defined as a sequence of (x,y,z) *points*. For example, a wing's upper surface contour line may be defined as a sequence of (x,y,z) points at 0% (leading edge), 5%, 10%, 20%, 35%, 50%, 65%, 80%, 90%, 95%, and 100% (trailing edge) chord. Each point within a single contour line need not be unique. LaWGS allows no more than 50 points per contour line.

The figure below portrays the concepts of *contour lines* and *points*.



The LaWGS format uses sequential, formatted, list-directed FORTRAN 77 READ's and WRITE's. This essentially means that all character strings must be enclosed within single quotation marks (') and all numeric values must be separated using one or more blanks, a comma, or any combination of the two.

The very first record within a LaWGS file is the configuration name (an 80-character text string), enclosed within single quotation marks. We recommend that you also include the date when the file is created.

The following sequence of records is repeated for each component:

The second record is the first component's name (an 80-character text string), also enclosed within single quotation marks. Each component name should be unique from all other component names.

The third record (often called the "component header record") contains the following values:

component # (integer)
number of contour lines (integer)
number of points per contour (integer)
local symmetry indicator (integer)
0 - no symmetry
1 - reflect across the local XZ plane
2 - reflect across the local XY plane
3 - reflect across the local YZ plane
x-axis rotation (real)
y-axis rotation (real) (all rotations use the right-hand rule)
z-axis rotation (real)
x-axis translation (real)
y-axis translation (real)
z-axis translation (real)
x-axis scale factor (real)
y-axis scale factor (real)
z-axis scale factor (real)
global symmetry indicator (integer)
0 - no symmetry
1 - reflect across the global XZ plane
2 - reflect across the global XY plane
3 - reflect across the global YZ plane

The fourth and subsequent records contain the (x,y,z) coordinate data. How many data are written to each record is not important. The order of the (x,y,z) data is significant. That order is:

the (x,y,z) coordinate of the first point along the first contour line
the (x,y,z) coordinate of the second point along the first contour line
.
.
the (x,y,z) coordinate of the last point along the first contour line

the (x,y,z) coordinate of the first point along the second contour line
the (x,y,z) coordinate of the second point along the second contour line
.
.
the (x,y,z) coordinate of the last point along the second contour line
.
.

the (x,y,z) coordinate of the first point along the last contour line
the (x,y,z) coordinate of the second point along the last contour line
.
.
the (x,y,z) coordinate of the last point along the last contour line

The transformations indicated on the component header record are executed in the following order:

1. local symmetry
2. rotations (x-axis, then y-axis, then z-axis)
3. translation
4. scaling
5. global symmetry

Note that if either local and global symmetry are non-zero, a single reflected image of that component is created. If both symmetry indicators are non-zero, three reflected images of that component are created.

Appendix C
The TOAD Format (summarized)

The Transferable Output ASCII Data (TOAD) format was developed by Computer Sciences Corporation for NASA Langley Research Center as a uniform way to store and retrieve tabulated data. A full discussion of the TOAD format is presented in NASA Contractor Report 178361. However, most readers will find the following abbreviated description adequate for their purposes.

TOAD files are sequential-access and formatted, using fixed-length records of 80 characters. This file type makes them simple to edit, write to or read from magnetic media, or send across communications networks. Unfortunately, these same characteristics make them large compared with their unformatted, variable record-length counterparts. Therefore, we recommend that TOAD files be used only when relatively small amounts of data are to be retained (less than 5000 pieces of data), or when any amount of data must be transferred from one computer to another (usually different) computer via magnetic media or a communications network.

Blocks of information within a TOAD file are called "warts." Each wart has its own purpose, and may use one or more records. For example, consider the abbreviated TOAD file below:

```
BEGIN
SKIP Predicted aerodynamic properties of a modified F-4D fighter
COUNT            9
LABELMACH           ALPHA          2Y/B           CL-V           CD-V
     CM-V           CL-Z           CD-Z           CM-Z
DATA    .85000000E+00  .10000000E+01  .70800000E+00  .97261000E+00  .15166000E+00
      -.24139000E+00  .88951000E+00  .11640000E+00 -.24754000E+00
DATA    .85000000E+00  .10000000E+01  .79200000E+00  .89415000E+00  .11423000E+00
      -.27911000E+00  .78920000E+00  .69700000E-01 -.27105000E+00
DATA    .85000000E+00  .10000000E+01  .87500000E+00  .78330000E+00  .72870000E-01
      -.29796000E+00  .65651000E+00  .19080000E-01 -.26920000E+00
END
```

Notice that the file begins with a BEGIN wart and ends with an END wart. The SKIP wart is used to insert comments inside the file. The COUNT wart indicates that there are 9 variables in this TOAD file. The LABEL wart assigns a 15-character name with each of these variables. Each DATA wart contains information gathered at some common event. For example, the second DATA wart indicates that at Mach .85, 10 degrees angle of attack, and at 79.2% semispan the full vortex flow coefficients of lift, drag and moment (C_l, C_d and C_m) are .89415, .11423 and -.27911, respectively, while the zero leading-edge suction coefficients of lift, drag and moment are .7892, .0697 and -.27105, respectively.

The FORTRAN 77 edit descriptors for each type of wart are:

Wart Type	Write Format	Read Format
SKIP	'SKIP ',A75	T6,A75
COUNT	'COUNT',I15	T6,I15
LABEL	'LABEL',(5A15)	(T6,5A15)
DATA	'DATA ',(5E15.8)	(T6,5E15.8)

The following rules must always be observed when creating and using TOAD files:

1. Exactly one BEGIN wart must appear in the TOAD file, and it must be the very first record.
2. Exactly one END wart must appear in the TOAD file, and it must be the very last record.
3. A COUNT wart must appear before any LABEL, UNITS, or DATA warts.
4. No wart may come between two records within another multi-record wart.
5. SKIP warts may appear anywhere in the TOAD file, subject to condition 4.
6. Multiple DATA warts are expected. All DATA warts must contain the same amount of data and use the same number of records.
7. There is no limit on the number of warts or records in a TOAD file.

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15. Supplementary Notes

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16. Abstract

The Pressure Visualization (PreViz) package is a software tool which merges a wireframe model of the test aircraft with pressure data represented as a series of displacement vectors normal to the aircraft's skin. The PreViz package automates much of the researcher's data reduction effort, reduces the time required to review large amounts of pressure data, presents the data more clearly than tabular listings, and provides a wireframe description for a black and white graphic suitable for a technical publication (the actual graphic images must be created by a local package - PreViz has no graphics capability). Although designed for pressure data, the PreViz package works equally well for any surface property (such as structural loading or skin temperature). Written in ANSI-standard FORTRAN 77 and self-contained, PreViz executes in UNIX, VAX/VMS, and CDC/NOS host environments.

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